PhD Dissertation Defense Announcement
Mechanical and Aerospace Engineering Department
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Infrared and Fluorescent Thermal Imaging and Thermal Transport Characterization of Engineering Devices and Systems

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Abstract

Infrared (IR) thermal imaging is widely used for non-contact temperature measurement in engineering. IR camera detects thermal emissions from the target surface in a certain wavelength range, which, using the known surface emissivity, can be converted to a pixel-by-pixel temperature map. Fluorescence imaging also works along similar lines.

This Ph.D. dissertation contributes towards thermal imaging and thermal transport characterization in engineering devices/systems using infrared and fluorescence imaging. In the first two parts of this work, infrared thermal imaging is used for measuring thermal conductivity of thin wires and for spotting unusual activities in a three-dimensional integrated circuit (3D IC). In the third part, a fluorescence imaging technique is developed for non-contact temperature measurement of a Li-ion cell with the help of a standard camera (mobile or DSLR).

Measuring and understanding thermal conductivity is key for thermal characterization of materials and for maximizing performance and thermal safety of engineering devices and systems. This study presents a comparative method for measuring thermal conductivity of a thin wire. The method is based on infrared thermography of the wire of interest suspended from a high temperature base. Through comparison of thermal response of the wire with that of a standard wire of known properties, thermal conductivity is measured for several wires in a broad range of thermal conductivity. Measurements are reported for both low thermal conductivity polymer wires and high thermal conductivity metal wires.

In the second part, infrared thermal imaging along with image analysis algorithms have been used for hardware trojan detection in microprocessors. Modern microprocessors are highly susceptible to hardware and software Trojans. Such Trojan activities may slow down the microprocessor, or in a worse case, leak confidential data and incapacitate microprocessor functionality. In principle, abnormal circuit activity due to Trojan operation is expected to cause distortion in the temperature field of the IC due to Joule heating. This study carries out measurement of temperature field of the transistor plane of a two-die three-dimensional integrated circuit (3D IC) thermal test chip through backside infrared imaging. Four distinct image processing algorithms are evaluated and compared in terms of speed, accuracy and occurrence of false positives and negatives.

Finally, a fluorescent thermal imaging technique is developed for a non-invasive temperature measurement of Li-ion cells during charge and discharge. The fluorescence signal goes down as the temperature of the target increases. A novel non-contact temperature measurement technique is developed by calibrating this over a desired temperature range. This study focuses on the development of material patches containing the fluorescent dye that can be attached on the target surfaces for non-invasive thermal measurements. As an outcome of this project, a normal image captured using a phone camera can be utilized to measure the temperature of the target objects. In this work, steady state as well as transient temperature measurements are carried out for li-ion cells fixed with fluorescent dye patches while operating them at various charging-discharging rates. The technique may have applications far beyond Li-ion cells.